RESULTS OF FURTHER EXPERIMENTS ON TABLE MOUNTAIN FOR ASCERTAINING THE AMOUNT OF MOISTURE DEPOSITED FROM THE SOUTH-EAST CLOUDS.

By R. Marloth, Ph.D., M.A.

(Read March 29, 1905.

(Plate I.)

It will be remembered that about two years* ago I laid before the Society the results of some observations on the amount of moisture deposited from the south-east clouds on Table Mountain, and that in summing up these results I stated "that the object of my work had been to ascertain more exactly the climatic conditions under which the plants on the mountain existed. That side of the question has been answered. Their summer is not dry. Their climate is that of a swamp—a permanent swamp in winter, a periodical swamp in summer, which dries up during a long spell of fine weather, but becomes soaking wet during the days of the south-east cloud. These results explain why such luxuriant and thickly-set vegetation prevails on the upper parts of our mountains . . . and why there are little lakes, even late in summer, on the top of Table Mountain, as well as close to the summit of Dutoit's Peak. . . . The purely meteorological side of the question I leave to others for further investigation."

The method employed consisted in keeping two 5-inch rain-gauges on the top of the mountain—one of the ordinary kind, and the other one surmounted by a framework which carried an imitation bunch of reeds 1 foot high. The quantities which I had obtained in my measurements were, however, so large that they met with a considerable amount of doubt, although I had taken special care to point

* R. Marloth, "Results of Experiments on Table Mountain for Ascertaining the Amount of Moisture Deposited from the South-east Clouds" (Trans. S.A. Phil. Soc., vol. xlv., p. 403, 1903).

out that I did not look upon them as representing a corresponding rainfall.

The main objection raised against the method of measurement employed was that an isolated group of reeds might capture such a quantity of moisture, but that others standing behind the first one or the first row would not be able to do so, owing to the front row acting as a screen and straining the moisture out of the passing cloud—that, in fact, there would not have been sufficient moisture left to supply the reeds in the rear.

The Society having decided that further experiments were desirable, the Council requested me to undertake them, voting at the same time the necessary funds for the acquisition of additional gauges. With the help of some friends and the assistance of the city water-engineer, Mr. Wynne-Roberts, and a member of his staff, I was enabled to continue the observations for two years; hence I think that it may interest some members of the Society to hear what has been the result of this work.

Before stating these results I should like to refer briefly to the main objection mentioned above, and to see what an amount of moisture would be available in a south-east cloud. In order to simplify the calculations, I beg leave to employ metric measures, and I shall put the height of the mountain, roughly, at 1,000 m., the exact figure being 1,082 m. The lower limit of the cloud varies, of course, considerably; but it may be put at an average of 600 m. above sea-level, which means that each layer of the cloud, from the time it is formed until it reaches the summit, has to ascend 400 m.

As the air at the lower limit of the cloud is saturated with water vapour, apart from the water in liquid form which is suspended in the air and forms the cloud itself, and as such air with an initial temperature of, say, 20° C. reduces its temperature by 0·44° C. for every 100 m., the total decrease of temperature during the rising from the 600- to the 1,000-m. level would be 1·72° C.*

If the temperature of fully saturated air of 20° C. be reduced by one degree, a condensation of 0·98 grammes of water will take place in every cubic metre of such air; hence in our case 1·68 grammes of additional water—above that which originally formed the cloud—would be floating in every cubic metre of air on its arrival at the eastern edge of the top of the mountain.

The velocity of the south-east wind has been found occasionally to exceed 40 miles an hour; but let us take a velocity of 20 miles

* These calculations are based upon Hann's "Lehrbuch der Meteorologie," pp. 240, 241.

only, which corresponds, roughly speaking, to 8 m. per sec. As there are 3,600 seconds in an hour, a velocity of 8 m. per sec. means that during one hour 28,800 cub. m. of air would pass successively over the same surface of 1 square m.; and as each cubic metre of air is carrying 1·68 grammes of suspended water, the total quantity of it passing this area would be 48,384 grammes, a quantity which, if deposited on an horizontal surface of 1 square m., would be equal to 48 mm. of rain, or, in round figures, 2 inches per hour.

That is taking into consideration only a layer of air 1 m. thick; but the cloud is often 100 or more metres thick, and as the masses of cloud in their course over the mountain are hurled and whirled about, any portion of the lower layer, that may have been deprived of its suspended moisture by the reeds, is constantly mixed with fresh masses from above, and there is evidently much more moisture available than many miles of reeds * could ever capture.

It is this large excess of condensed moisture which floats about in the cloud in the form of small drops that accounts for the surprisingly large deposit of water on the reeds and rocks and all other obstacles in their way. Not all clouds possess such a soaking effect. I have sometimes spent many hours on the mountain in thick clouds without finding any moisture on the bushes or any water in my gauges. That is specially the case during northerly winds; but when a real south-easter blows things are quite different, and I am sure it would simplify the discussion considerably, if some of the sceptics would give me the pleasure of their company on such an occasion.

Such a cloud is really an intimate mixture of an ordinary cloud with a very finely distributed rain in its initial stages, and as this mass is moving with great velocity, the minute raindrops are not allowed to fall, and are captured only when they come into contact with a solid body.

Another objection against the method employed, and the conclusions drawn from the observations, has been laid before this Society by Mr. Charles Stewart,† in a paper read in July, 1903, and entitled "A Note on the Quantities given in Dr. Marloth's Paper on the Moisture Deposited from the South-east Clouds." Mr. Stewart took considerable pains to calculate the total surface of the vertical superstructure employed by me, and found that the vertical "catchment area" of the gauge, *i.e.*, the surface of the framework, reeds, and other parts amounted to 114 square inches, which is six times as much as the horizontal area of the gauge. I am much

* I repeat the explanation on p. 404 of my previous paper, that these plants are not real reeds, but resemble them only, belonging to the order *Restionaceæ*.

† Charles M. Stewart, B.Sc., Trans. S.A. Phil. Soc., vol. xlv., p. 413, 1903.

obliged to Mr. Stewart for this calculation, for it enables those who are not familiar with the internal condition and state of a south-east cloud to recognise at a glance what an enormous surface a bunch of reeds only one foot high exposes to the passing cloud. When, however, Mr. Stewart goes a step further, and divides the total quantity of moisture collected in the gauge by the number of vertical square inches found by him, and gives the factor obtained in this way as the true deposit of moisture per square inch of the gauge, I fail to comprehend his reasoning.

My 5-inch gauge carried twenty-four vertical wires and reeds, corresponding to 176 reeds per square foot of ground. If we find that a layer of water 1 inch thick has been deposited on a piece of ground 1 square foot in extent, we must conclude that the plants growing on that patch have this quantity of water at their disposal, the usual losses, of course, being left out of account. What could it matter, as far as the recording of a quantity of water per square inch is concerned, whether this water was collected directly from rain by the horizontal surface of the ground or indirectly from the clouds by means of the 176 vertical reeds standing on this area?

There are several other misunderstandings in Mr. Stewart's paper which would require adjustment, but I fear that this would take up too much of the time of the Society. I must, however, refer to a source of error which has not been mentioned as yet.

During my earlier experiments I had assumed that the difference between the records of the two gauges, viz., the ordinary rain-gauge and the reed-gauge, represented only moisture captured by the reeds, exclusive of all rain. From the daily readings of the gauges at the Woodhead reservoir it is, however, apparent, that during rain the gauge with the reeds collects much more water than the open one. There is no uniform ratio between the two, the gauge with the reeds showing during ordinary rain from three to four times as much as the other one; but during "misty" rain, when the open gauge records sometimes only $\frac{1}{100}$ or $\frac{1}{10}$ of an inch, the capture of the reeds was ten or even twelve times as much.

This variation of the ratio shows how effective the vegetation is in comparison with the bare ground or rocks in capturing moisture apart from the real rain, but it will be impossible to ascertain exactly how much be due to the one source and how much to the other. As these experiments were never intended to give accurate quantitative returns which could be entered alongside the rainfall records, but merely to demonstrate that much more water was deposited on the mountains than the ordinary rain-gauges indicated, especially in summer, it will not matter if we exclude all the periods during which any rain was recorded, and utilise for our purposes only those records which are not affected by this error.

The following Table gives a summary of the results for periods during which no rain was observed:—

	Woodhead Reservoir. Alt. 2,496 feet.		Maclear's Beacon. Alt. 3,500 feet.		
	Inches.	Number of days.	Inches.	Number of days.	
December, 1903.	1·35	8	—	—	Gauge standing in the open
January, 1904...	1·58	5	9·55	7	
February, 1904.	2·18	6	4·56	9	
March, 1904.....	3·72	7	5·0	5	
January, 1905...	3·14	12	—	—	
February, 1905.	2·31	9	—	—	

One of the special questions I wanted to decide in my recent experiments was to ascertain, to what extent reeds and bushes were sheltered by others standing in front of them. For this purpose I had placed one gauge in the open as before, one in the midst of a thicket of bushes 5 feet high, and one in the centre of a field of high reeds, the upper surface of which was level with the top of the frame of the gauge. The gauges near Maclear's Beacon were read weekly, and another one at a lower elevation, viz., in front of the caretaker's house at the Woodhead reservoir, daily, by Mr. Thorsen, who took great interest in the work. The following table gives his observations for one month of each year, the other months being practically of the same nature.

We found that there was a considerable screening effect exercised by the outer rows of bushes and reeds, especially during short periods of clouds, but that the quantity which did reach the sheltered gauges during longer periods of south-east clouds was far in excess of the total of the rainfall for the summer months. On an average the gauge in the interior of the thicket of bushes captured about one-third of that in the open, while the gauge which was practically hidden in the reeds collected from one-fourth to one-eighth of the amount recorded by the gauge in the open.

In connection therewith I may state, that I have checked these figures on several occasions by ascertaining the yield of the gauges during periods of one or two hours only. Sometimes even the gauge in the open captured practically nothing from the passing mist, while on other days one could watch the water dropping in.

Water Collected by the Ordinary Rain-gauges and Gauges with Reeds on Table Mountain.

Near Maclear's Beacon. Alt. 3,500. January, 1904.			Woodhead Reservoir. Alt. 2,496. January, 1904.			Woodhead Reservoir. Alt. 2,496. January, 1905.		
Date.	Rainfall.	Gauge with Reeds.	Rainfall.	Gauge with Reeds.	Wind and Weather.	Rainfall.	Gauge with Reeds.	Wind and Weather.
1					W., fine		**1·12**	Strong S.E., misty
2	0·61	4·75	0·53	2·37	Rain during night			Fine, S.E.
3					N.W., cloudy			Fine, N.W.
4			0·04	0·12	S.E., misty		**0·13**	Light S.E., mist during night
5				**0·02**	S.E., slight mist			Light S.E.
6	0·04	4·40			S.E., strong		**0.24**	N.W., misty, cloudy [night
7					S.E., strong	0·45	6·15	N.W., misty, rain during
8					S.E., strong	0·10	0·82	N.W., misty, light showers
9			0·70	1·80	N.W., rain during night	0·44	1·80	N.,misty,cloudy,light showers
10			0·27	3·05	N.W., rain during night	0·21	0·83	N., misty, light showers
11			0·11	1·25	N.W., rain during night			N., light, fine [ing night
12	0·65	20·62	0·07	0·22	Misty, cloudy		**0·31**	N., light, misty, and S.E. dur-
13					S.E., misty		**0·10**	S.E., misty, cloudy
14				**0·12**	S.E., misty		**0·57**	S.E., misty, cloudy
15			0·01	1·02	S.E., misty and cloudy			S.E., fine
16				**0·02**	S.E., strong			S.E., fine
17	0·03	8·10			S.E., light			S.E., fine
18					N., light			W., light, fine
19				**0·97**	S.E., misty		**0·02**	N.W., moderate
20			0·01	2·17	S.E., misty and cloudy			S.E., fine
21				**0·45**	S.E., misty and cloudy			S.E., fine
22					Fine		**0·15**	S.E., fine, misty during night
23					N.W., fine		**0·25**	S.E., misty during night
24		**9·55**			S.W., fine	0·03	**0·40**	S.E., misty, cloudy, slight rain
25					S.W., fine [night			S.E., cloudy
26			0·09	0·15	N.W., light rain during	0·01	1·41	S.E., misty, cloudy
27					N.W., cloudy		**0·15**	S.E., slight mist
28	0·11	0·85			N., light and cloudy		**0·03**	S.E., fine [night
29					S.E.	0·21	1·36	S.E., misty, slight rain during
30					S.E.		**0·02**	S.E., fine
31		**0·15**			S.E.			S.E., fine
Tls.	1·44	48·42	1·83	13·73		1·45	15·86	

It had been my intention to include all these figures in this paper, when a period of south-east clouds of unusual duration and vehemence rendered this quite unnecessary. You will no doubt remember that at the end of February and the beginning of this month a violent South-east storm raged throughout South Africa for nearly a week. There were abundant rains in all the eastern, southern, and central parts of the Colony, as is usual during such a severe S.E. wind, but no rain of any significance fell during that time on the Peninsula or in its neighbourhood. The gauges had been read on Saturday, the 25th of February, and, noticing some signs of a change of weather on Friday, the 3rd of March, I went up that afternoon to read them again, although the storm was still raging with unabated vigour.

I am almost afraid of stating what I found in the gauge standing in the open, for it was equal to 21·2 inches of rainfall. We may,

Photo by R. Marloth. West, Newman proc.

THE LAKE ON THE TOP OF TABLE MOUNTAIN WHICH OWES ITS PERMANENCE TO THE S.E. CLOUDS.

however, leave this figure out of account altogether, for the gauge which was practically hidden in the reeds, just as if it were standing in the midst of a luxuriant cornfield, showed 6·1 inches of moisture, and that for a period of six days, during which the ordinary rain-gauge at Maclear's Beacon recorded 0·15 inches of rain. I think it will be admitted that there are no other figures wanted. As a matter of fact, for any one who visited the mountain on that day or soon afterwards no figures were necessary at all to convince him of the enormous quantity of water which this south-easter had left on the mountain.

The upper plateau was practically a swamp from one end to the other; everywhere one met with pools of water; the little lake on the top had double the size and depth it usually possesses at the end of the summer, and the few late blooms of the gorgeous *Disa uniflora*, which I found in the fir-tree valley, were partly submerged on the borders of the swollen stream. And there had been no rain worth mentioning for 23 days.

As stated in my previous paper, I do not look upon these figures as being equivalent to records of rainfall as far as the general water supply of the streams is concerned, for during rain a great deal of water runs off from the bare rocks and reaches the streams immediately, while this moisture is captured only where sufficient vegetation exists, which, on the other hand, retains a large proportion of it in the spongy root work. Yet observations and gaugings made at some of our larger mountain streams have shown, that a considerable rise of the rivers may be effected by a long-continued south-east wind, although no rain had fallen in the catchment area.

There can be no question that the vegetation of our mountains is a very important factor in the regulation of the water supply of the springs and streams, and that this influence is exerted in two ways. Firstly, by capturing a not inconsiderable amount of moisture from the south-east clouds, which would escape if the mountains were formed by bare rocks only; and, secondly, by protecting the water which has accumulated in the soil and the rocks against the sun and consequent rapid evaporation. With regard to the loss due to evaporation I may be allowed to mention the experience of the Cape Orchard Company at Hex River.

Mr. Dicey has kindly informed me, that the mountain stream, which the Company uses for driving their Pelton wheel, gives them in summer 60 horse-power, but that on bright days the quantity of water in the stream generally decreases so much that about 2 p.m. they cannot obtain more than 55 or 54 horse-power. Towards evening it rises again and regains its full force by 11 p.m.